A View of the Forest Products Industry from a Wood Energy Perspective

Introduction

The Forest Products Industry comprises the forestry, lumber, wood product, and pulp and paper industries. The scope of operations of the Forest Products Industry includes forest management, timber harvesting and processing, construction materials, furniture manufacturing, and pulp and paper manufacturing. The Industry is central to providing raw material for manufacturing products such as transmission poles, boats, mobile homes, musical instruments, transport trailers, recreational vehicles, and sporting goods.

In order to understand the material presented in this article, it is essential to understand U.S. forest resources, their availability for fuel, and the ownership patterns of wood resources in varying regions of the United States. EIA has provided material on these topics in a prior issue of this publication. Chapter 6 of *Renewable Energy Annual 1995*[1] presents information on U.S. forest resources, timber harvests, forest residues, and waste wood resources. Specifically the following information is included:

- Net volume of timber (by region, species group, and timber class)
- Volume of roundwood[2] harvested for pulpwood and fuelwood (by region, species group, and timber class)
- Weight and energy yield of roundwood harvested for fuelwood
- Wood supply from logging residues (and other removals from noncommercial growing stock)
- Bark and residue from primary wood-using mills used for fuel (by region, species type and material used for fuel).

Appendix E of the same report shows timber ownership patterns in the United States, as well as regional removals from growing stock and other sources. As will be discussed later, timber procurement in the United States does not follow uniform, well-established practices, compared with those in the coal and natural gas markets. Thus, the added complexities in biomass fuel procurement can pose a challenge to increased biomass energy output.

The goals of this article are to (1) define the Forest Products Industry, (2) establish the approximate size and character of Industry subgroups that are important from an energy perspective, (3) identify the factors that most influence the energy profiles of these subgroups, and (4) identify and characterize the most important manufacturing processes used by the subgroups in terms of their energy profiles, and how influencing factors are likely to change them. This article does not discuss electric utility use of biomass to generate power.

Many external information sources were investigated to support this analysis. Primary sources consisted of company annual reports, government studies, proposed and final government agency rules, industry investment analyses, trade and environmental association data and position papers, Census Bureau data, and personal communication with industry experts.

The Forest Products Industry

The Forest Products Industry contributes significantly to the Nation's economy and employment base and accounts for 7 percent of national manufacturing output.[3] According to the American Forest and Paper Association (AFPA), its membership posted recent sales of about $230 billion per year[4] at 550 mills employing 1.6 million people in 46 States.[5] Major end-use markets of

[1] Energy Information Administration, *Renewable Energy Annual 1995*, DOE/EIA-0603(95) (Washington, DC, December 1995).

[2] *Roundwood* is a term used by the Forest Service and the Forest Products Industry to denote commercial grade wood cut from the main parts of the tree as opposed to residues from small limbs, bark, and stumps.

[3] American Forest and Paper Association, "Quick Facts About America's Forest & Paper Industry," undated brochure.

[4] *Ibid.*

[5] American Forest and Paper Association undated pamphlet, "Summer 1996 Quick Facts About America's Forest & Paper Industry."

the Forest Products Industry include new construction (primarily residential housing), remodeling and repair, publishing and office products, and converted paper and paperboard (cartons, bags, boxes, and containers). The Industry exported $7 billion worth of wood products and $11 billion worth of paper products in 1994.[6]

The pulp and paper industry is a major subgroup of the Forest Products Industry. The North American pulp and paper industry is frequently referenced in a global business context. Newsprint and pulp are two very important commodities of both the U.S. and Canadian forest products industries. In general, the U.S. and Canadian forest product industries share many similar market and manufacturing characteristics. Both industries appear also to employ the manufacturing machinery of a key set of vendors and have a high degree of commonality in processes and procedures. Many of the largest forest product companies have important operations in both the United States and Canada, with a number of international headquarters located in Canada.

On closer inspection, however, these markets are not totally seamless. Dissimilarities in government policy, energy resources, and raw material availability, as well as other factors introduce distinctions between the industries in the two countries.

U.S. and Canadian mills combined supply about 36 percent of the world's paper.[7] The Canadian pulp and paper industry registered recent annual sales of $29 billion, making it the country's largest trade contributor.[8] The total primary energy demand of the Canadian pulp and paper industry was about 750 trillion Btu in 1994. By comparison, the total first-use energy (formerly referred to as primary consumption) by the U.S. pulp and paper industry measured by the Energy Information Administration (EIA) in 1994 was *2,665 trillion* Btu.[9] Company-wide sales of U.S. pulp and paper industry participants are estimated at $110 billion.[10]

Wood products account for approximately 47 percent of the industrial raw material manufactured in the United States. Like all forest products, they undergo the first stages of manufacturing as harvested lumber. From an energy perspective, initial operations center around four primary product categories—sawed lumber, primary engineered wood products (i.e., plywood and panels), pulpwood and fuelwood—followed by a key group of secondary products. Secondary products include flooring, siding, molding, and other products characterized by finish-milling. An extended group of secondary wood processors includes manufacturers of furniture, mobile homes, musical instruments, boats, cartons, pallets, transmission poles, etc. A common trait shared by these manufacturers is their use of the commodity wood products (provided by primary wood product or key secondary wood product suppliers) to make durable goods or value-added nondurable goods. Larger quantities of wood are handled by primary wood processors. Consequently, from an energy perspective, more wood fuel and wood residue/by-product fuel is utilized by these businesses than is the case with other processors, sometimes called secondary mills.

Primary wood processors directly access the fiber supply resource base, either from owned timberland or on a contractual basis from a well-established network of timber owners and wood suppliers. The large volumes of wood involved in these transfers create a favorable cost basis for primary processors. The favorable cost basis extends to the use of roundwood for fuel and supply by vendors of hogged fuel.[11]

The Forest Products Industry uses wood waste as fuel for producing steam and electricity to support manufacturing. Although it is only the third-largest consumer of electricity, the Forest Products Industry self-generates more electricity than any other U.S. manufacturing group. The paper and allied products subgroup self-generates the largest percentage of its total electricity requirement of any major industrial sector (Figure 1).

The *2,665 trillion* Btu consumed by the pulp, paper, and paperboard subgroup in 1994 represented 3 percent of total U.S. energy consumption. The majority of this energy was supplied by domestic fuel sources, with 56

[6] American Forest and Paper Association, undated pamphlet, *U.S. Forests 1995: Facts and Figures*.

[7] Gary A. Smook, *Handbook for Pulp and Paper Technologists*, 2nd ed. (Angus Wilde Publications, Vancouver, B.C., 1992).

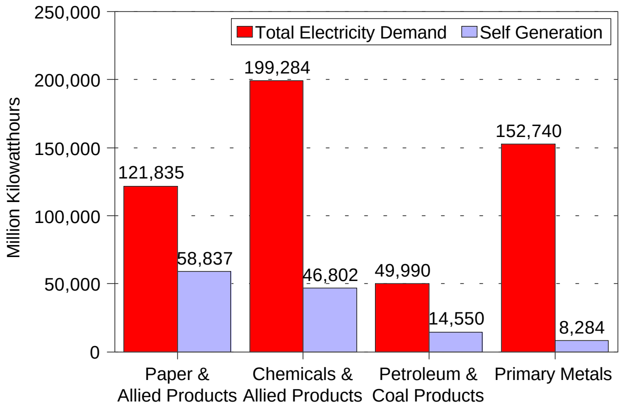
[8] Paprican/Canadian Pulp and Paper Association news release dated October 21, 1996, Vancouver, B.C., Canada.

[9] Energy Information Administration, *Manufacturing Consumption of Energy 1994,* DOE/EIA-0512(94) (Washington, DC, December 1997), p. 37.

[10] Because several U.S. companies significantly involved in pulp and paper operation also operate in other industries, this estimate is greater than U.S. pulp and paper industry sales. See the following section for a further explanation of the actual size of U.S. pulp and paper operations.

[11] *Hogged fuel* is wood that has been made into chips in a tub grinder or hammermill. The residues from timber harvesting (called slash) or silviculture are sometimes used as a source of wood for hogged fuel.

Figure 1. The Largest U.S. Electricity-Consuming Industries and Their Generation, 1994



Source: Energy Information Administration, *Manufacturing Consumption of Energy 1994*, DOE/EIA-0512(94) (Washington, DC, December 1997).

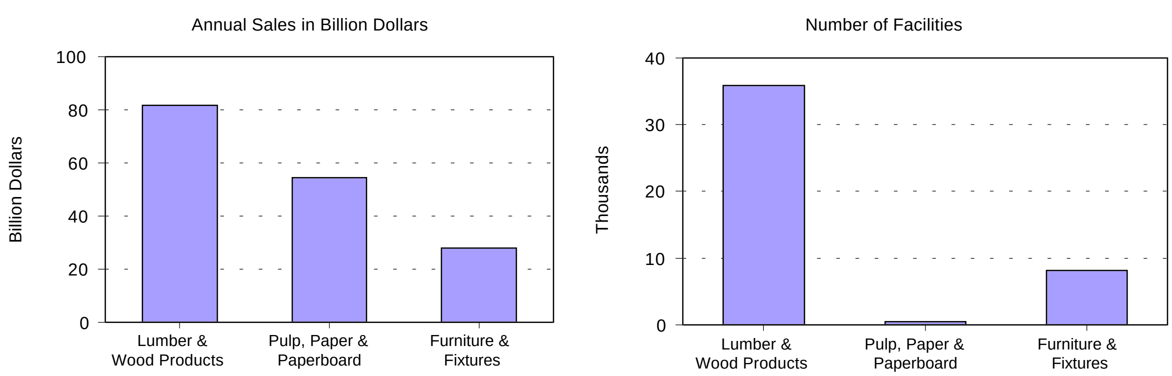
percent supplied from within the industry.[12] These factors are highly significant from an energy security standpoint. Canada's forest products industry has a comparable level of self-sufficiency.

The Structure of the Forest Products Industry

Fairly extensive government and trade data exist for the pulp and paper subgroup of the Forest Products Industry. In part, this is because pulp, paper, and paperboard mills are large, have a work force of just a few hundred, and receive statistical attention as an important, major primary wood processing subgroup. Less data exist for secondary mills, sawmills (a primary wood processing group), and fuelwood processors because their facilities are usually smaller and number in the thousands. In some cases, secondary mills produce a broad range of commodities and value-added products, which also contributes to the unavailability of detailed data.

The Census Bureau, using the Standard Industrial Classification (SIC) system, reports industrial activity according to specific end-product manufacturing categories.[13] Large corporations, of course, do not always conduct business according to sharply defined product and industry distinctions. Their corporate divisions frequently manufacture products in several of the cited categories. Figure 2 identifies some of the characteristics of three key SIC industries that include major wood processors.[14] Subgroups of these industries that are not primary or key secondary wood processors were not included in the summary data on which the figure was based. For example, the subgroups of the SIC for paper and allied products, which primarily manufacture bags and cartons from purchased mill stock, were eliminated. The adjusted subgroups that result are highly wood energy-intensive.

Figure 2. The Three Largest Wood Processors in the Forest Products Industry, 1992



Source: Selected data from the U.S. Department of Commerce, Bureau of the Census, *1992 Census of Manufacturers* (Washington, DC, 1992).

[12] American Forest and Paper Association, *Fact Sheet on 1994 Energy Use in the U.S. Pulp and Paper Industry* (Washington, DC, March 27, 1996).

[13] This system makes the following designations pertinent to this discussion: SIC 24, *Lumber and Wood Products*; SIC 25, *Furniture & Fixtures*; SIC 26, *Paper and Allied Products*. The Energy Information Administration's Manufacturing Energy Consumption Survey reports according to this system.

[14] All the data in this section are taken directly or adjusted from that contained in U.S. Department of Commerce, Bureau of the Census, *1992 Census of Manufacturers* (Washington, DC, 1992).

It is interesting to note that while nearly 36,000 businesses make up the adjusted lumber and wood products subgroup, only 529 mills constitute the pulp, paper, and paperboard products subgroup. With respect to employment profiles, only 19 percent of lumber and wood product businesses employ more than 20 people, compared to 98 percent of pulp, paper, and paperboard businesses. The lumber and wood products industry is a significant component of American small business and a key factor in the national rural economy.

Census data indicate that 72 percent of pulp mills, 95 percent of paper mills, and 89 percent of paperboard mills produce all of their primary manufacturing inputs. These data, supported by information in annual reports, demonstrate that pulp, paper, and paperboard manufacturers represent a major market for lumber and wood products companies, especially in the logging subgroup of the latter.[15] In turn, the paper industry unquestionably supports thousands of small businesses and is important to the rural economies of several regions. Likewise, some large corporations also participate in the fiber supply infrastructure via their raw material and commodity divisions.

As stated above, corporate ownership characteristics do not always link conveniently to specific SIC's. Company annual reports and investment analysis publications provide some of the detail to better understand front-end industrial processes.[16] These processes consume most of the primary manufacturing energy used in the forest products industry. Investment publication data aggregated for this paper reflect that 1995 sales by the 25 largest U.S. corporations classified as *primarily* pulp and paper manufacturers totaled $110 billion. Comparison of this information to the pulp and paper sales data in Figure 2 indicates that approximately half the business volume of these corporations is in products other than pulp and paper commodities.

Although these companies are diversified into a few unrelated areas, their operations portfolios reveal that most of their non-pulp-and-paper business is related, being mainly found upstream or downstream of primary operations. That is to say, pulp and paper companies are frequently vertically integrated either on the raw material side of primary manufacturing (i.e., forestry and logging) or on the finished product side. The latter category includes converted paper products such as boxes, containers, sanitary products, and coated or laminated papers. Acquisitions and mergers have resulted in a substantial restructuring of the pulp and paper industry, causing it to become less fragmented and more global.[17] As an example, a divestiture was recently announced by a large American container manufacturer that transferred ownership of a $1.5 billion pulp and newsprint subsidiary to a Canadian company.[18] Examples of horizontal integration include operations such as sawmills; veneer and panel board mills; and flooring, siding, and structural product mills. The characteristics of these 25 largest pulp and paper corporations are differentiated by their mix of integration in such areas. Some are oriented toward raw material resources, while others concentrate on finished goods, production, and consumer marketing.

Miscellaneous Converted Paper Products, a second paper-related SIC category isolated for this article, converts a small amount of wood-based waste to energy. Analysis of this sector indicates that converters are heavily concentrated in populous states with a heavy manufacturing and consumption base. Adding directly related[19] Census data for this SIC category (about $40.4 billion in 1992) to the aggregate sales of the selected wood processors in Figure 2 yields an adjusted total of $204.4 billion in 1992. This total (adjusted for interim economic growth up to the same statistical year for comparative purposes) is very similar to the AFPA estimate of Industry sales volume of $230 billion cited earlier.

Factors Affecting Energy Profiles of the Industry

Technology and environment are highly related factors which affect the use of energy in the Forest Products Industry, particularly in the pulp, paper, and paper board subgroups. Before discussing these topics in detail, an overview energy profile of the Forest Products Industry is presented.

[15] The logging subgroup furnishes pulp, paper, and paperboard manufacturers with "raw" wood from which pulp and paper mills make their manufacturing inputs (e.g., wood pulp).

[16] These processes include raw material handling, processing, and first-stage conversion, which is essentially the manufacture of commodity fiber products, which in turn are used as raw material for finished fiber products in later processes.

[17] Celso Foelkel, "Finance and Marketing Conference Provides International Industry Outlook," *TAPPI Journal,* August 1997, p. 234.

[18] *The Wall Street Journal, Business Briefs,* "Stone Container to Sell Its Pulp, Newsprint Lines, and Pare Debt," October 28, 1997.

[19] The plastic bag subdivision's $5.7 billion contribution was subtracted.

Energy Profile

In the Forest Products Industry, a large proportion of self-generated energy is derived from the waste wood by-products of production. Large amounts of energy are required for the drying process, the operation of kilns, and for steam and electricity production to power mill processes. Wood is used advantageously to satisfy part or all of the energy needed for these purposes. In the major wood-processing industries, manufacturing output not only determines the level of demand on timber resources for raw material inputs for a typical mill or facility but also strongly affects the rate of utilization of wood as fuel. Expressed in different terms, average wood raw material and wood waste usage profiles are sometimes predictable within a certain range for given products and processes.

For particular businesses, however, the ratio of wood used as a primary fuel to manufacturing output is not as predictable as in the forest products industry as a whole. Wood's use as a primary fuel may be strongly influenced by factors such as wood resource ownership, accessibility (in terms of both quantity and species), stumpage rates,[20] and the age and type of combustion system employed. Additionally, the strength or weakness of market demand for a facility's products, consequently its throughput, can influence the primary fuel, electricity, and / or steam consumption profile, as can on-hand capability to change manufacturing output to a different product. The ability to substitute products in reaction to market conditions is in some cases a determinant of profitability.

Environment and Technology: Factors of Pivotal Influence

Environmental laws, regulations, and policies affect the Forest Products Industry in two general areas: (1) wood production and (2) manufacturing. Environmental policy[21] strongly influences management and use of timberland, which is the Forest Product Industry's source of raw material. Industrial air, water, and waste management policy exerts a powerful influence on manufacturing operations. Industrial environmental policy has shaped the methods by which the Industry has made its products and generated and consumed energy for the past three decades. Today, the Industry deals with few aspects of energy without considering environmental factors, and vice versa. Environmental considerations are, in fact, key determinants of this manufacturing sector's energy profile. The energy characteristics of key Industry processes reflect this dynamic. However, many regulatory programs have matured, and Federal and State agencies are changing their enforcement focuses and strategies. Recently, governments have replaced some mandates with voluntary practices and industry initiatives. Some of them permit operational changes to be made according to individual plant equipment replacement schedules. Such changes have thus been important in changing the mode of operation of the Forest Products Industry.

Technological Innovation

Historically, technological innovations that changed or influenced output capability (mill capacity) were implemented as developed and were somewhat independent of environmental influences. In the past two decades, however, these two issues have become more closely linked.

A recent study determined that between 1900 and 1975 gross output per day of a sample of fine[22] paper mills was between 200 and 450 tons per day. Mills built after 1975, however, began to approach 1,200 tons per day in output. The study's author stated, "Expansions tend to occur together as firms identify the same window of market or technological opportunity."[23] Technical opportunities occurring in the 1970's included automation using electronic sensors and computer-aided manufacturing. (The study also helps to illustrate another important phenomenon—the cyclical nature of the paper

[20] The stumpage rate is the value or rate paid to purchase standing trees for harvest. Stumpage is usually defined as standing live or dead uncut trees. " Waste" is the volume of timber that should have been removed during harvesting and is subject to stumpage.

[21] To summarize laws and regulations affecting the Forest Products Industry, it can be noted that a 1993 Forest Service study indicates that 117 State and 522 local laws and regulations influencing the use of timberland were in effect (U.S.D.A. Forest Service, *RPA Assessment of the Forest and Rangeland Situation in the United States–1993 Update*, Forest Resource Report No. 27 (Washington, DC, June 1994), pp. 24-25. These statutes regulate timber management and harvesting, protect the general environment and sensitive habitat, preserve wooded areas, control water pollution and stream sedimentation, and protect roads and bridges. Availability of sawtimber, pulpwood, and wood chips for boiler fuel is sometimes affected by these constraints. For example, it was estimated that a 1 to 3 percent reduction of usable fiber supply nationally resulted from these State and local regulations.

[22] The reference is to paper grade.

[23] David M. Upton, Harvard Business School, "Computer Integration and Catastrophic Failure in Flexible Production," (working paper, Harvard Business School, 1994), Figure 1. The effect of market forces on Forest Product Industry output was discussed in the Energy Information Administration, *Renewable Energy Annual 1996*, DOE / EIA-0603(96) (Washington, DC, March 1997).

industry—which is not related to the focus of this article.)

During the same time the mills were achieving increases in capacity through automation, the sweeping provisions of the National Environmental Policy Act[24] began to be implemented. The revolution in digital technology that occurred during this period also influenced methods of environmental regulation. As electronic technology increased in sophistication, many of the measurement and recording capabilities critical to environmental monitoring programs became feasible.

New Processing Technologies

Today, new or newly-adopted chemical, mechanical, and biological processing technologies are being tested and employed in the paper industry. A primary driver of this change is environmental concern with toxic air emissions, toxic effluents, and solid waste by-products.[25] Although wood pulping and papermaking comprise only one of the regulated Forest Products Industries, they are the focus of great regulatory attention. This is due to their facilities being quite large and the fact that they utilize highly complex chemical, thermodynamic, and mechanical processes that can generate toxins.[26] A discussion of a few of the most important interrelated technology, environment, and energy topics related to the most energy-intensive industrial processes follows.

Extensive review reveals that the ideal solution to environmental pollution in the paper industry, from a regulatory perspective, is closed-cycle processing. This operational concept is applicable to other major industries, such as the chemical and metal industries, as well, but it is most relevant to papermaking in the Forest Products Industry. The key features of the closed-cycle approach[27] are (1) total reclamation of process water and chemicals, and (2) close automation linked to continuous monitoring and recording of effluents and emissions.

A number of alternatives to closed-cycle processing involve substitution of less harmful chemicals for the more reactive and potentially toxic agents formerly in wide use. In addition, some recent technological innovations involve alternative sequencing and combining of typical chemical agents as opposed to substituting new processes. Heat applied to these sequences is also closely monitored for optimal results. These process staging variations are customized for each mill, giving each its own energy and production economics profile. Processes using such innovations include combustion, the dewatering of pulping liquor and sludge, the deinking of newsprint recovered for recycling, medium consistency processing,[28] and high-intensity refining.[29]

[24] The National Environmental Policy Act became effective in 1970. It (1) established the *Council on Environmental Quality* (CEQ) under the Office of the President, (2) established a broad set of environmental policies, and (3) assigned and authorized specific Federal agencies to implement and enforce these policies.

[25] One of the most serious classes of pollutants involved is chlorinated organic compounds generated in pulp and paperboard manufacturing. These can result from the reaction of the organic compounds in wood with chlorine, which is frequently used in pulping, bleaching, and particle decontamination processes. Toxins in this category of pollutants can include dioxins and furans, and these carcinogens can result during downstream processes, such as pulping liquor dewatering or combustion.

[26] The largest industries, i.e., metals, petroleum, and chemicals, are regulated by EPA according to guidelines specific to those industries. The pulp and paper industry is regulated as a subset of *Chemicals and Allied Products*. Regulations stemming from the general body of air, water, and waste toxic laws are applied specifically to these industries by means of these specific guidelines. The set of guidelines that applies to the pulp and paper industry is currently being updated by EPA. As proposed, they have come to be known as the "Cluster Rules." The Cluster Rules have been strongly opposed by groups associated with logging and paper, including both industry and employee special interest groups. Generally, these interests agree that measures to protect the environment are necessary, but they advocate employment of less capital-intensive alternatives to closed-cycle processing and maximum achievable technology. Chief among the alternatives suggested is substitution of chlorine dioxide for elemental chlorine in pulping and bleaching operations, although there are several others. Total Chlorine Free (TCF) processes are advocated by environmental groups. Many plants have voluntarily switched to chlorine dioxide and the industry claims a highly positive environmental result. Chlorine dioxide is less reactive than elemental chlorine and is therefore less efficient from an operational standpoint. However, because it is less reactive, chlorine dioxide generates smaller amounts of chlorinated organic toxins and achieves a better, although not perfect, environmental performance. The final Cluster Rules ruling by EPA is pending but has not been registered as of final print.

[27] This analysis is indebted to the wealth of information contained in several studies on the pulp and paper industry by Energy Mines and Resources Canada and the Center for Mineral and Energy Technology; the discussion is based heavily on this information from here forward.

[28] This term refers to methods involving more extensive breakdown of wood fiber into smaller or more easily processed shapes by mechanical means, as compared to conventional practice.

[29] Compared to conventional methods, high-intensity refining involves the use of one or more of the following: a greater concentration of pulping and bleaching chemicals per unit of fiber volume in a containment vessel of a given size; mechanical mixing to permit more extensive contact of chemical agents with fiber surfaces; thermal mixing; and change in the sequence or intensity of conventional pulping and bleaching stages (which involve the application of chemical agents singly or in combination).

Industry size and pollution profile are important determinants of environmental policy and regulatory focus. Smaller scale forest product industries are usually both less energy intensive and less regulated. In the plywood and panel manufacturing industry, energy is consumed mainly for drying raw material and forming products. Environmental regulation is concerned primarily with the toxic volatile agents released by the adhesives and binders used in these products. Toxic substances or precursors in new adhesives[30] have been greatly reduced. Drying of wood fiber is critical to the proper adhesion of the binders and glues used in plywood and panel products and accounts for a great deal of energy use. Structural products, e.g., composite beams, are related in this respect but manufacturing processes more commonly apply mechanical energy than thermal energy in product forming.

By comparison, the dimension lumber, flooring, siding, and pole industries are fairly energy intensive because of the raw material and finished product drying that is frequently required. Treated lumber also receives attention from environmental regulators as a result of the treatment of products with toxic preservatives.

Energy Implications of Environmental and Technological Transition

Kiln Drying

A significant amount of energy is consumed by industrial operations such as wood pulping and drying. Kilns are enclosures or large machines used to dry products like lumber, poles, and raw materials such as the veneered wood and core fiber used in plywood panels. Large quantities of poles are manufactured for use in telephone signal and electricity distribution. Kiln drying is an energy-intensive process that is essential for imparting desirable properties to wood, including dimensional stability, workability, and hardening (e.g., as is required for tools), and promoting better absorption of treatments or adhesives. The United States Department of Agriculture's Forest Product Laboratory research indicates that drying operations more commonly burn wood wastes rather than fossil fuels for their energy source.[31]

Frequently, rail-mounted platforms carry the wood material in and out of a kiln. The kiln chamber is then sealed and heat is applied by steam or direct-fired air. Sometimes pressure or a vacuum is introduced into the chamber, depending on the product. Typical kiln temperatures range between 200 and 230 degrees F.[32] While absolute estimates of the energy used in kiln drying are highly specific to the conditions of a given operation, engineering data indicate that steam applied and maintained at a temperature of near the 230-degree-F limit permitted by the American National Standards Institute standard will apply heat to a product surface at a potential rate of roughly 22,000 Btu per square inch. Drying times generally vary from 1 to 6 days. Longer drying times are required for wood that receives oilborne or preservative treatments. Subjective anecdotal information indicates that the energy required to dry about 500 cubic feet of lumber from an as-received condition to a 20-percent wet basis moisture content is approximately 10 million Btu.

Poles were air dried before the late 1960's, but the majority are now kiln dried, due to the shorter residence time involved. Research on air circulation and optimum temperature and residence schedules have resulted in technologies which have reduced original kiln drying energy by as much as half of previous requirements.[33] In addition, some electricity is used as motive force for fans and product repositioning during drying. Environmental concerns involve emissions from kilns,[34] combustion systems, and treating agents.[35] Waste heat from kilns can be recovered by means of heat exchangers. Wood-drying kilns have been suggested as a candidate technology using ground-source heat pumps for supplemental energy.

[30] According to the Hardwood Plywood and Veneer Association (Internet Web site: http://www.erols.com/hpva as of July 1, 1997), manmade synthetic resins were introduced in veneer and plywood products in the 1920's and 1930's. Prior to this time, solely animal and plant adhesives were used.

[31] R. Sidney Boone, U.S.D.A. Forest Products Laboratory, "Drying of Southern Pine Poles for Preservative Treatment," *Proceedings of the 1st Southeastern Pole Conference*, November 8-11, 1992, Starkville, MS; Madison, WI: Forest Products Society: 157-162; 1994.

[32] *Ibid.*

[33] *Ibid.*

[34] Major direct emissions of concern from kilns used to dry large-scale timber (which includes utility poles) are water vapor, volatile organic compounds (e.g., methanol), and creosote. In addition, there is concern about the emissions from the sources of energy used to provide heat to the kiln (electricity and, for direct heat, usually wood waste).

[35] For poles, there are additional potential toxic releases from oilborne or preservative treatments.

Waste-to-Energy

Sawmills convert timber to dressed logs and lumber, some of which are then kiln dried, as just described. The wood waste produced by sawmills is frequently used as fuel. In fact, a typical modern sawmill produces enough waste to exceed its own energy requirement of 113 kilowatthours per ton of wood processed (equivalent to 2.25 million Btu) by 10–30 percent.[36] In some cases, waste wood in excess of requirements is used for a variety of products or for other fuel purposes (e.g., as a raw material for charcoal). Environmental concerns with sawmills are mainly focused on alternatives to stockpiling excess sawdust and finding product uses for waste to avoid the use of landfills. According to the APA—The Engineered Wood Product Association[37]—85–90 percent of the log is typically used. The bark, sawtrim, and remaining sawdust are used for energy or pulpchips. Production of additional electricity and steam for sale are also energy products. Sales of electricity to the grid, of electricity and steam to industrial customers for process energy, and of steam for district heating fall into this category.

Improvements in resins and epoxies permit clamping to replace thermosetting for some products in the engineered wood products industry with a resultant savings in energy. However, use of phenolic resin, which requires thermosetting and has some adverse environmental characteristics, is still common. Plywood and oriented strandboard markets accounted for more than half of the total demand for phenolic resin.

Bleaching

Paper companies make a host of products requiring the use of technically complex chemical, thermal, and thermochemical processes. These processes involve numerous stages and combinations of stages. Each major process is defined by distinct energy and environmental characteristics. Delignification of pulpwood and bleaching of wood pulp involve the most environmentally sensitive group of processes, due to the byproducts that result in mill effluents. The most prevalent bleaching technology currently used involves some form of chlorine. Using chlorine is economical and results in high process efficiencies. One reason chlorine is economical is that it is co-produced with sodium hydroxide, an agent required in large quantities during another stage of papermaking. The chlorinated organic compounds generated during chlorine processes are serious toxins and are a primary focus of regulation in the United States, Canada, and Europe.

Mill effluents currently require treatment by one of several methods, depending on the particular mill.[38] A variety of new technological strategies to reduce chlorinated organics are now being employed, or considered, to achieve compliance with pending regulation. These pollution reduction methods can be categorized in three ways: (1) substitution of other chemical agents for chlorine, (2) recovery of some of the chlorine used and incineration or secondary treatment of the remainder, or (3) use of closed-cycle technology in new or reconstructed mills. All these options involve increases in capital and operating costs. However, each has a different energy profile. Overall, the paper and pulpboard manufacturing industry consumed an average 26 million Btu per ton of output in 1994, but the trend in energy use in this sector is downward.[39]

The Canada Centre for Mineral and Energy Technology (CANMET) has completed a definitive study of the pulp and paper industry. Several reports produced from this study form the informational basis on which the following discussion is based.

No increase in steam consumption is required to implement the first alternative to chlorine bleaching—chemical substitution. Oxygen delignification, for example, does not require as great a degree of pulp and water heating. However, this process requires more electricity to bleach paper than if chlorine dioxide were used. As mentioned previously, chlorine dioxide is essentially co-produced "free" at the bleaching plant. The second option, recovery or treatment of chlorine, increases primary energy consumption and in some cases doubles it. An increase in total primary energy is also associated with the third option, closed-cycle processing, although it has other advantages previously mentioned. This option,

[36] Energy Information Administration, *Renewable Energy Annual 1996*, DOE/EIA-0603(96) (Washington, DC, March 1997), p. 25.

[37] This organization is the result of two prior groups, the American Plywood Association and the Engineered Wood Product Association.

[38] A pilot program called Project XL, initiated by EPA, seeks to encourage innovation by industry in pollution reduction. XL is an acronym for "excellence and leadership." An international standard, ISO 14001, dealing with mill environmental management, can be part of an XL permit. On January 17, 1997, EPA issued a news release entitled "EPA Reaches Agreement on XL Project With Weyerhaeuser Co." Under this agreement, Weyerhaeuser's Oglethorpe, GA, pulp mill will reduce the amount of chlorine compounds it uses and decrease its water usage to 10 million gallons a day, compared to the industry mill average of 25 million gallons. Weyerhaeuser gains by the agreement in that it is awarded the latitude to make process changes more quickly.

[39] The American Forest and Paper Association, *Monthly Statistical Summary* (Washington, DC, July 1996).

however, is not expected to be prevalent before the year 2010.

In 1993, CANMET established energy and material baselines to characterize papermaking methods. Energy and material use have subsequently been projected to future years. As a result of all process changes, total electricity consumption for bleaching is expected to increase 7 percent between 1993 and 1997.[40] Electrical energy costs represent 8 percent and steam represents 17 percent of bleaching expenses in Canadian mills.[41]

Closed-cycle processing requires extensive reconstruction or total facility replacement and is currently employed in only a few mills. However, closed-cycle and minimized effluent designs are likely to become more common in the next few years. State and Federal regulatory agencies are granting more latitude to mills that incorporate such improvements. This factor is critical in the highly competitive paper industry, where profitability frequently hinges on the speed with which these immense plants can diversify products and redirect mill output from poor to favorable markets. Such latitude may be especially attractive to the paper industry because production flexibility by means of computer integration has not been completely successful.[42] Nearly one-half the mills in operation after 2010 may be closed-cycle facilities (Table 1).

Other Innovations

Other recent technological innovations do not replace old processes, but represent variations of established methods of dealing with by-products or using chemical agents in various process stages. These innovations include extended delignification, biomass dewatering and combustion, dewatering of pulping liquor and sludge, deinking of newsprint (from recovered paper), medium consistency processing, and high-intensity refining.

Table 1. Selected Papermaking Technologies Ranked by Industry-Wide Energy, Economic, and Environmental Benefits and Predicted Extent of Use in Canada

Technologies	Total Energy[a]	Primary Energy[b]	Electricity	Environ-mental Impact	Economics	Predicted Extent of Use (percent)	
						2000	2010
Suspension Firing	1	1	8	5	3	28	45
Biomass Dewatering	2	2	5	6	2	58	74
Deinking of Newsprint	3	8	2	8	7	58	78
High-Intensity Refining	4	9	1	10	1	40	61
Medium Consistency Processing	5	5	3	9	4	40	65
Deinking Sludge Incineration	6	3	6	4	5	42	69
Fluidized-Bed Combustion	7	4	7	7	6	20	34
Closed-Cycle Bleached Kraft Mill	8	7	4	2	8	16	44
Secondary Treatment of Effluents	9	6	10	1	10	88	95
Oxygen and Ozone Bleaching	10	10	9	3	9	61	79

[a]Total Energy is the sum of fossil fuel consumption by the five sectors (residential, commercial, industrial, transportation, and electric utility) plus hydroelectric power, nuclear electric power, net imports of coal coke, and electricity generated for distribution from wood, waste, geothermal, wind, photovoltaic, and solar thermal energy.

[b]Primary Energy is the sum of fossil fuel consumption by the four end-use sectors (residential, commercial, industrial, and transportation) and generation of hydroelectric power by nonelectric utilities.

Notes: See text for explanation of technologies. "1" denotes most favorable, "10" least favorable.

Source: Canada Center for Mineral and Energy Technology, Efficiency and Alternative Energy Branch, "Research and Development Opportunities for Improvements in Energy Efficiency in the Canadian Pulp and Paper Sector to the Year 2010," February 1993, p. xiii.

[40] Canada Centre for Mineral and Energy Technology, Energy Efficiency Division, *Chemical Pulp Bleaching: Energy Impact of New and Emerging Technologies*, January 1994, p. 37.

[41] *Ibid.*, p. 38.

[42] David M. Upton, Harvard Business School, "Computer Integration and Catastrophic Failure in Flexible Production," (working paper, Harvard Business School, 1994), Figure 1. The effect of market forces on Forest Product Industry output was discussed in the Energy Information Administration, *Renewable Energy Annual 1996*, DOE/EIA-0603(96) (Washington, DC, March 1997).

Extended delignification involves longer residence time for wood chips in digesters and it is characterized by both higher steam and electricity consumption rates.[43] Biomass dewatering and combustion by suspension firing are similar. Typically, mill sludge is dewatered before it is used for fuel. In suspension firing, sludge and hog fuel are dewatered in mechanical presses, further dried by use of hot flue gas, hammermilled to a fine form, and fired in a boiler. Biomass dewatering and suspension firing offer several benefits, including substantial savings in primary energy, significant reduction in combustion emissions, and favorable process economics.

Fluidized-bed boilers have the capability to burn undewatered sludge, which can be an important capability to newsprint mills as use of recovered paper continues to increase and deinking results in increased quantities of sludge. Fluidized-bed boilers also contribute to reductions in fossil fuel emissions. However, they require new construction, whereas suspension boilers can be retrofitted.

Medium-consistency processing involves the use of higher concentration ratios of fiber to process water. This type of processing can claim only modest energy and environmental impact, and its commercial use may not occur until after the year 2000.

High-intensity refining involves changes in the operational parameters of the machinery used to break down fiber for pulping. Its use causes very little change in total primary energy consumption *(large* savings in electricity are offset by higher direct heat requirements) and has minimal environmental impact.

Table 1 ranks these technologies and predicts their acceptance by industry, based on a survey of Canadian mills. The significance of environmental impact can be seen in the table's rankings for Secondary Treatment of Effluents. Although this technology is the least favorable from an economic standpoint and ranks among the lowest in terms of energy consumption, it is the most environmentally favorable technology, and it has the highest predicted extent of use by the years 2000 and 2010.

Future Use of Biomass Energy

Biomass is the second-largest of the renewable energy sectors (after conventional hydroelectric), with wood comprising the largest component of biomass energy. The largest use of wood for energy occurs in the Forest Products Industry. Congress is discussing several bills that would increase the quantity of renewables used to generate electricity. Three important factors should be considered by policymakers as they see ways to increase the use of renewables in electricity generation:

- By far, the largest proportion of current wood-based electricity generation occurs in the Forest Products Industry (there are now only a handful of wood-fired utilities in the United States).

- Primary forest product industries are located in close proximity to timber resources. In contrast, utilities are generally located near population centers. This is of particular concern to generating plants wishing to fire with wood-based products, because transportation of wood-based energy products is much less economical than for coal.[44]

- The supply of commercial forest resources is limited and distributed among competing uses.[45] Forest product industries enjoy a well-established supply infrastructure and would be reluctant to force prices higher for pulp and other products due to an increased demand for fiber in generating electricity.

Some scenarios for greatly increased biomass-energy use rely heavily on the assumption that fluidized-bed combustion (FBC) units and combined cycle generators will offset possibly higher biomass fuel costs through energy-efficient operation. This assumption is likely to be true for generation-only plants. As Table 1 shows, however, FBC technology generally does not have very good economic, energy, or environmental characteristics in the near term, when applied by pulp and paper manufacturing.

Biomass-oriented generating plants yet to be built could indeed have an energy-efficiency advantage over some

[43] Fiber breakdown by pretreatment of wood chips with a fungus that occurs naturally is used for a process, now in demonstration stage, called biopulping. An advantage of biopulping, developed by the Forest Products Laboratory and a paper industry consortium, is lower primary energy requirement.

[44] The relative inefficiency is due to two factors: 1) The energy density of wood is about half that of coal; and 2) Harvesting wood uses far more acrage in a less efficient fashion for an equivalent weight of product than for mining coal.

[45] The time horizon referred to here is 10 years. Trees grown for energy, such as willow and poplar, require at least 10 years growth before they can be harvested. Thus, the wood resource base under consideration here is confined to existing forests.

of the conventional combustion systems now in use in the Forest Products Industry. However, in the near term they are certain to face disadvantages. Biomass-generating plants must locate near[46] fuel resources, especially because of their established fuel supply infrastructure. At the same time, these facilities need to be located near existing electricity transmission lines. In contrast, pulp and paper manufacturing plants are located near their fuel resources as well as the point of electricity demand. These issues are only a few of the two-edged considerations associated with possible legislative mandates for higher renewable electric generation. Another is the cost-effectiveness of locating generating facilities near population centers, where the cost of land is high or possibly prohibitive. Yet biomass energy has demonstrated favorable environmental, employment, and energy security characteristics and is generally considered to be CO_2-neutral. The challenge of broader implementation of biomass for energy is to gain the wider involvement of those entities most able to participate, as well as to stimulate new industry.

Although certain sectors of the Forest Product Industry would indeed resist diverting more biomass resources for energy, the fact is that the majority of timber grown in the United States is available to the winning bidder. Forest product industry members are generally not self-sufficient in supply, so they purchase needed biomass products from producers or other intermediaries. Generally, these resources are nonindustrial private forest landowners not under long-term contract. Further, current forest removal (i.e., utilization) rates are such that a substantial supply of logging residue is available. Therefore, at a sufficient price, energy interests could obtain additional biomass resources. The above statements are generally more true in the East, where most wood is purchased directly from the producer.[47]

Another factor operating in energy interests' favor is that a significant volume of wood is consumed as fuelwood for home heating. The value of forest removals for this purpose is generally less than that of timber removed for industrial products. Thus, energy interests could obtain additional fuelwood without having to compete with industrial interests.

Finally, forest products companies are seeking new ways to increase timber resource utilization. One possibility is to convert logging slash into a usable product. Members of the Forest Products Industry, a very significant potential participant, have mixed views on the increased use of wood for electricity generation. Some, such as those in the pulp and paper subgroup, believe that increased demand on wood supply would drive up resource costs and place a greater strain on already tight profit margins. Others in the industry who are well situated with respect to resource ownership, or whose resource divisions are very profitable, may view biomass energy as a favorable opportunity. Regardless of resource position, biomass energy producers may increase their generation if they can operate profitably on wood fuel priced competitively with stumpage that might otherwise go for pulp and paper manufacturing. Considering all viewpoints, however, two key questions relating to the area of governmental policy seem to be emerging: Will renewable energy mandates, if enacted, stimulate the birth of a new renewable-based generating industry, with survival qualities yet to be determined? Will the Forest Products Industry overall be a formidable obstacle or a willing participant in additional biomass energy generation?

[46] A conventional rule is that biomass can be gathered economically for energy use within a 50-mile radius of the combustion site.
[47] In the West, forest industry companies currently procure much of their resources from publicly owned lands, though this is changing.